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IMPORTANCE OF GEOTHERMAL ENERGY IN THE AREA OF SEMBERIJA IN THE REPUBLIC OF SRPSKA

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Abstract: The increasing demand for energy, and environmental protection in recent years, has given an even greater importance to the use of alternative renewable energy sources. One of the most important sources of energy, used worldwide for more than 100 years, is geothermal energy. Its presence in the waters and rocks opens the possibilities for its wider use for various purposes. It plays an important role in the developed countries or in the countries that are more focused on the use of geothermal energy. However, compared to the fossil fuels that are the main source of energy, geothermal energy is used only in negligible percentage.

Sudden environmental pollution in recent years, opened more space for the use of geothermal energy. Balkan countries have an important place on geothermal map of Europe, and Bosnia and Herzegovina, i.e. the Republic of Srpska stands out as a significant area where geothermal energy is accumulated as an important resource.

In the Republic of Srpska there are more characteristic areas with the presence of thermal waters, but the most important is Semberija, where the temperature at depths of 1200 – 2500 m ranges from 75 – 100 ^{0}C. Possibilities of using this energy are multiple, such as heat for various purposes or in electric energy production. Its use, in the area from which it is exploited and in the area where it would be used, will change the quality of the environment because it will partially or completely replace the current use of fossil fuels.

Keywords: geothermal energy, thermal water, limestone, heat energy.

1. INTRODUCTION

Energy, as an important factor of development of human civilization has had different roles over time, and has always been necessary to a certain degree. At the beginning of its use, energy sources were different and mainly in line with the needs, that were significantly lower than what nature can offer. At that time only the energy of renewable character was used, while at the time of accelerated industrial development, especially in 20th century, started an intensive use of the energy from fossil fuels started. This trend continued at the beginning of 21st century, so very soon we will face a situation where the fossil fuels cannot meet the needs of industrial development, i.e. total needs of human civilization.

Sudden use of fossil fuels as the energy source disrupted the balance both on the surface of Earth, as a planet, and its atmosphere. Natural soils, which make close-to-surface and surface part of the ground are polluted, and partly the ground waters too, and to the highest degree, air. All this gradually changed the climate on the planet, jeopardizing not only the human development of civilization, but also the flora and fauna and the Earth as a planet, in terms of the ratio of land and waters as a whole.

Fossil fuels that are currently most used will be less and less available in the future, as they are of limited nature as a resource, and their use leads to jeopardizing the environment. Consequently, today we have very often the energy crises that require the use of renewable, so far less significant energy sources. Besides water, which has been up to now significantly used as a source of energy, a possibility opens for geothermal energy from rocks and ground waters from different depths.

Geothermal energy takes a significant place in the world, with a considerable share in the energy balance of most countries. It is used as electrical energy and to a much greater extent as thermal

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energy. However, despite its significant presence in this area, it has not found great application yet.

2. BRIEF OVERVIEW OF DISTRIBUTION OF GEOTHERMAL ENERGY IN THE WORLD AND THE REPUBLIC OF SRPSKA

Today, as a source of geothermal energy, the energy of water accumulated in rocks is used, referred to as hydrogeothermal energy. Nevertheless, in everyday practice and in literature, this energy is most commonly referred to as geothermal energy.

The presence of geothermal energy is connected with tectonic processes, the areas with clear manifestations of volcanic activity, as well as with the orogene areas with the present processes of faulting and earthquakes. [1−5]. These are mainly the ridge parts of the continents, Figure 1, where we can single out:

- Eastern and southeast part of Asia,
- Western part of the overall American continent from USA through Central to South America,
- The European part stretching from the Mediterranean towards the central Europe. It is noteworthy that all the major islands in the east part of the Atlantic Ocean are rich in geothermal energy.
- South of the European continent, it stretches along the continental part of East Africa.
- Southeast of the European Continent, the geothermal activity is related to the area of mountain chains of Asia, in the territory stretching from Turkey, Iran, Afghanistan, Pakistan all the way to India and Nepal.

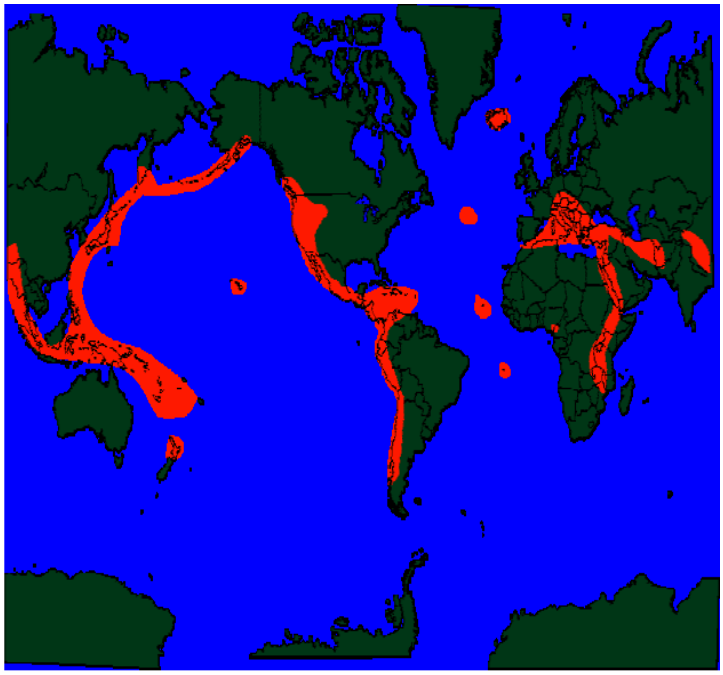


Figure 1. Distribution of geothermal energy worldwide

The distribution of geothermal energy in the area of Bosnia and Herzegovina, according to the geotectonic map [5,6] is connected with:

- Dinarides, Outer and Internal
- Southern rim of the Pannonian basin

A number of regions in which hydrogeothermal energy is accumulated are presented in more detail in Figure 2a. [5],

- Northern Bosnia (Semberija, Majevica and Posavina)
- Bihac-Kladusa area
- Una-Sana area
- Central part of Bosnia NW-SE (ophiolite area)
- Banja Luka-Sarajevo
- Central Bosnia region (divided in two parts)
- Eastern part of Bosnia
- Southeast part of Bosnia

Hydrogeothermal energy is accumulated mainly in limestone and dolomites, and its age ranges from Cretaceous era, Jurassic, Triassic to Paleozoic.

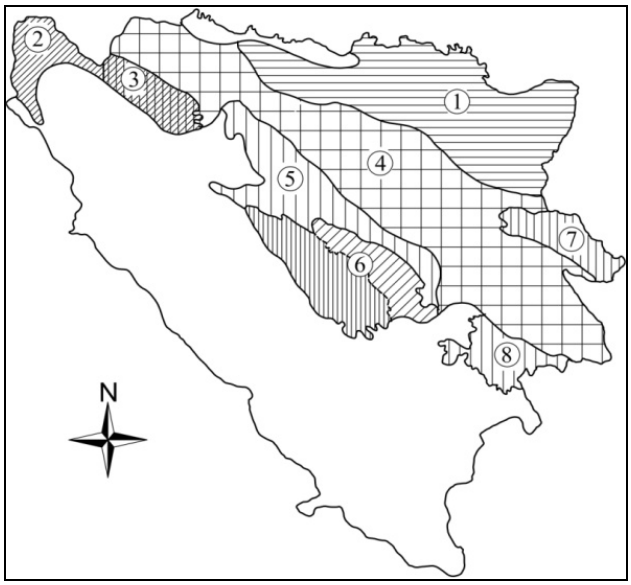
At a more detailed look, the following regions were singled out in the Republic of Srpska:

- Artesian basins of northern part of the Republic of Srpska (from the confluence of the Una river to Sava to the confluence of the Drina to the

Sava, covering the northern parts of the regions 2, 3, 4 and 1, presented in Figure 2b.

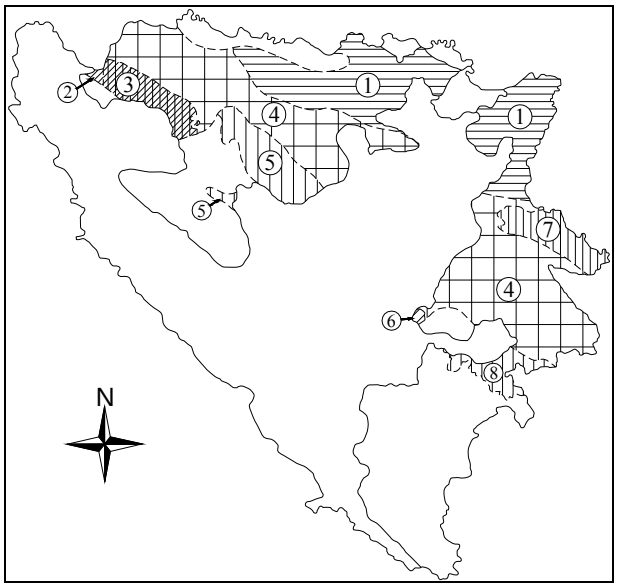
− The areas that belong to the Outer Dinarides, in which flysch rocks, ophiolites and contact metamorphic rock of the Prosara and the Motajica alternate, as well as the complexes of Cretaceous and Jurassic sediments, and these are the parts of the regions 3, 4 and 5.

− The areas with complexes of Cretaceous, Jurassic and Paleozoic sediments in the eastern part of the Republic of Srpska, parts of the regions 4,6,7 and 8.



a)

Figure 2a. Geothermal regions in Bosnia and Herzegovina (N. Miošić 1986, updated N. Đurić 1997)



b)

Figure 2b. Geothermal regions in the Republic of Srpska (N. Đurić 2015, according to the map of N. Miošić 1986): 1. North Bosnia, 2. Bihać-Kladuša, 3. Una-Sana, 4. Central part of Bosnia, 5. Banjaluka-Sarajevo,6. Central Bosnia region, 7. Eastern part of Bosnia, 8. Southeast part of Bosnia

3. GEOTHERMAL POTENTIAL OF THE REPUBLIC OF SRPSKA

The level of exploration of geothermal resources in the territory of the Republic of Srpska is connected with the previous Strategy of Studying Geothermal Potentials of Bosnia and Herzegovina back in the 1980s, when all the significant reservoirs were defined [5−9].

Today, in the area of the Republic of Srpska, hydrogeothermal energy of lower temperatures up to 75°C is only used, in the previously built capacities of a spa type, such as the spas: Dvorovi, Kozarska Dubica, Guber Srebrenica, Vilina Vlas Višegrad, Vrućica Teslić, Slatina Laktaši, Gornji Šeher Banja Luka and Kulaši near Prnjavor, Figure 3.

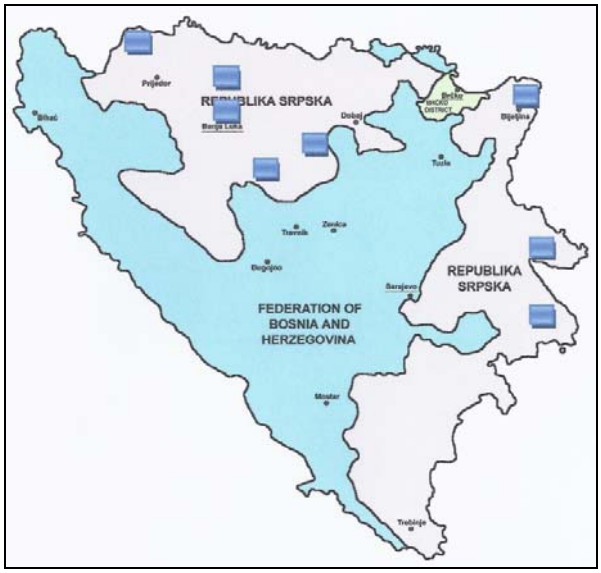


Figure 3. Spatial distribution of the spas in the Republic of Srpska

In the above-mentioned spas, the energy is used for different purposes:

− The waters in Dvorovi, Slatina, Kulasi and Visegrad are used for district heating, i.e. heating of mainly the spa facilities with the use of heat exchangers.

− Thermal and thermomineral waters in Toplice – Seher, Laktasi, Sockovac and Dvorovi are used for recreational purposes.

− Thermomineral waters in the area of Sockovac are used for extraction, i.e. production of CO_2 gas.

The degree of exploaration of these waters is much higher compared to their use.

4. GEOTHERMAL POTENTIAL OF THE WIDER AREA OF SEMBERIJA

The area of Semberija belongs to the region 1 in the North-East part of the Republic of Srpska, which, along with Majevica and Posavina, make the Geothermal Region of North Bosnia. In Southern part the region covers the parts of the Federation of Bosnia and Herzegovina too, which is another entity of Bosnia and Herzegovina. Geothermal energy in the Semberija area is very promising, however, very little exploited. The energy crises that occur from time to time refresh the considerations about the possibility of its use, but never enough to bring about concrete realization of a project. More than a half of the century was not enough to find economically feasible reasons for its use. Today, as we face not only the energy crisis, but also a threat to the environment caused by the use of energy from fossil fuels, geothermal energy in the Semberija area has become a significant alternative energy source. Its potential is considerable and the possibilities of its application manifold [10−14].

The first information about the presence of water with higher temperature was registered in mid-20th century during oil explorations. Three wells were drilled 1200-1500 m deep, quite sufficient to give up on further oil exploration, but sufficient to determine the presence of hot waters, that have a significant energy value. The above period was not interested in terms of use of energy from the wells that were made, so that they were closed down and abandoned. At the end of 1960s, a well was open in the settlement of Dvorovi near Bijeljina, and a possibility was analyzed to use water for appropriate purposes. Citizens were so persistent that in the area around the well the outdoor pools were soon constructed, and after that a structure of the spa type, which is today one of more significant spa facilities in the Republic of Srpska. Other wells remained closed and for now nobody knows in which state they are and if they can be brought into an appropriate condition for use.

By using geothermal waters from the said well, a route was opened for further research of geothermal potentials of the Semberija area and wider. After conducted explorations, the data was obtained showing that a significant reservoir of thermal waters exists in this area. Semberija is in the East part linked with Macva and probably with Srem too in the northern part, and with Posavina in the West, thus making a big reservoir of thermal waters with considerable energy potential, Figure 4. According to the available information, the site stretches across the minimum of 2.000 km^2, while the geothermal potential in the energy sense, while the geothermal potential in the energy sense as thermal equivalent has about 40 million tones of oil [15,16].

According to the said assumptions, more importance is given to geothermal energy in Semberija, where, according to some indicators, temperatures over 110^{0}C are expected. Thus a possibility of its use is opened not only for thermal purposes which has been a topic for more than 30 years, but also for generation of electricity. All the above, apart from economic effects, takes into account the environmental effects too, which are especially important in terms of the reduction of noxious gases, primarily of CO_2 in the atmosphere.

Figure 4. Geothermal potential of the wider area of Semberija along with Macva, Srem and Posavina

By making a deep GD-2well, at the beginning of 21st century at the location of "Slobomir" City, 1750m deep, with the temperature of 75^{0}C, geother-

mal potential of Semberija was confirmed. A geological profile that was established earlier from Bogatic to Bijeljina and further on towards the West, has been complemented with new data that confirmed the already made hypothesis on gradual settlement of layers from East toward the West. Thus, in Bogatic, the depth down to thermal waters in Triassic limestones is about 450m, and in the West part of Semberija the depth ranges about 2500m. There are more shallow horizons in Cretaceous limestones too, but the Triassic limestones at bigger depths are more important, Figure 5.

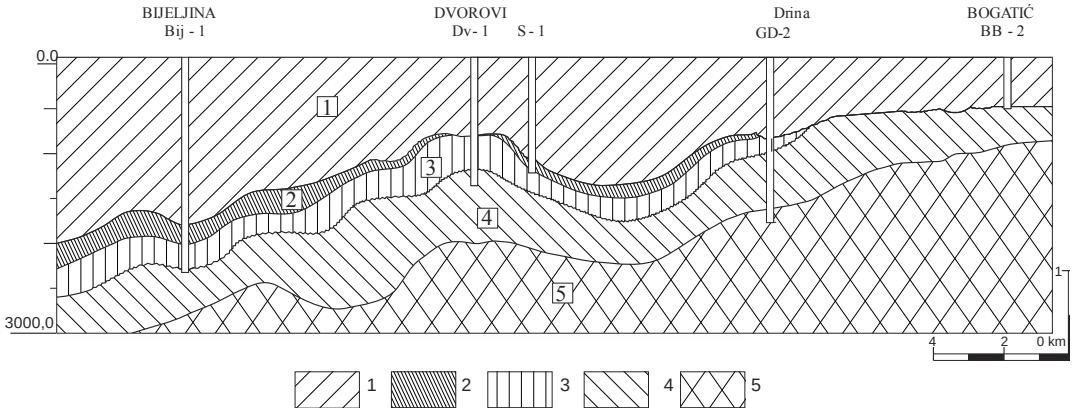


Figure 5. Geological profile of the Semberija ground
1. tertiary sediments, 2. Upper Cretaceous limestones, 3. Upper Cretaceous marls and sandstones, 4. Triassic limestones and dolomites, 5. bedrock sediments

The area of Semberija represents the young neotectonic depression which is filled with Neogene and alluvial sediments. Below the Neogene sediments there are cretaceous sediments (K) and Triassic sediments (T) [17]. The thickness of the Earth's crust in the area of Semberija is from 25.0 to 27.0 km [18], Figure 6. The geothermal field is made of the thermal field, i.e. the values of density of terrestrial heat flow and the temperature field, i.e. the values of temperate at different depths in the Earth's crust [19,20].

According to some researchers of this area, density values of the terrestrial heat flow in Semberija should be about 100 mW/m^2. These values are by about 50-80 % higher than the average values of terrestrial heat flow density for the continental part of Europe, which is about 60 mW/m^2. On Mohorovicic discontinuity where the limit between the Earth's crust and the mantle, from 25,0 – 27,0 km, the temperature value should be about 800 ^oC [18−20].

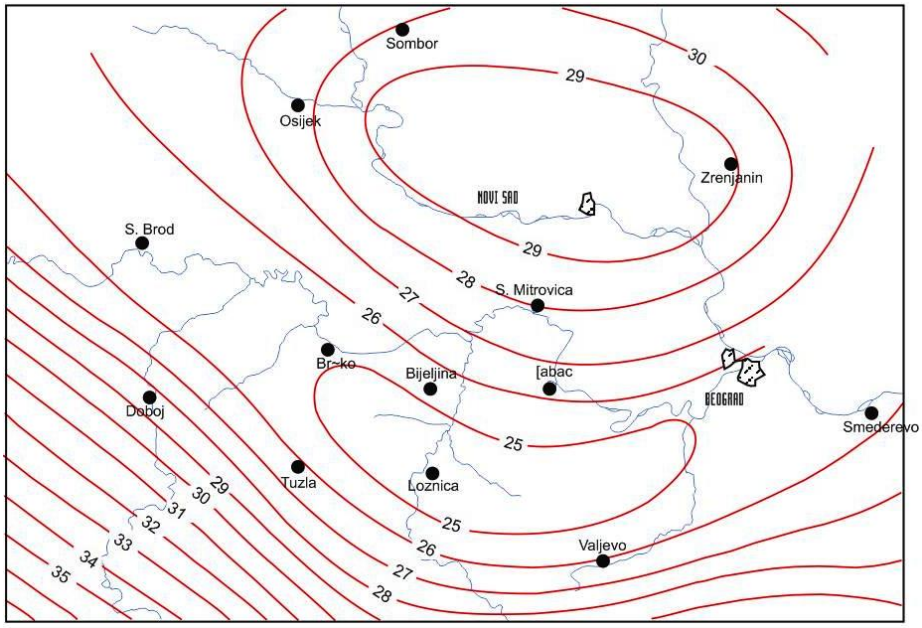


Figure 6. The map of isolines of the depth to the Mohorovicic discontinuity (km) (Dragašević et al. 1989)

Geothermal energy, accumulated in the territory of Semberija and in the immediate vicinity, was caused by above-the-average high values of density of regional terrestrial heat flow, which amounts to 95−112 mW/m^2. The main geothermal system is with thermal waters, where we have a hydrogeothermal system with convective transfer of heat within different reservoirs made of Mesozoic limestones. Above it there is a conductive system in Neogene sediments. There are indications that different reservoirs made of Mesozoic limestones (Cretaceous and Triassic) are hydraulically connected and that they make a very complex reservoir of hydrogeothermal system stretching in the area of Srem, Posavo-Tamnava, Macva and Semberija.

A hydrogeothermal system implies that part of the Earth's crust in which, apart from the conductive transfer, geothermal energy from the rock mass with the function of hydrogeological isolator, its convective transfer through the rock mass is conducted, with the function of hydrogeological collector filled with hydrogeothermal fluids. They can be rationally exploited and used as energy source comparable with other conventional energy sources [15,16].

Hidrogeothermal system in the area of Semberija is characterized by a reservoir which is located on Mesozoic sediments and is made of Upper Cretaceous limestones and Triassic limestones and dolomites, Figure 5. It represents a big unique Karst aquifer, with the waters of total mineralization are less than 1,0 gr/l.

Geothermal energy from the reservoirs of Upper Cretaceous limestones and its thermal waters has the following characteristics [15,16,21]:

− The total geothermal energy potential is about $230 \cong 10^6$ tones of thermally equivalent oil.

− The forecasted reserves of geothermal energy in the rock mass and thermal water of this reservoir are estimated to $57 \cong 10^6$ tones of thermally equivalent oil.

− Reserves in thermal water only are about $2 \cong 10^6$ tones of thermally equivalent oil.

Output temperatures of thermal waters from Upper Cretaceous limestones in the whole territory should be > 75^oC.

Geothermal energy in Triassic limestones and dolomites represent the main hydrogeothermal reservoir with the following characteristics [15,16,21]:

− Total geothermal energy potential of the reservoirs of Triassic limestones and dolomites is about $1170 \cong 10^6$ of tones of thermally equivalent oil.

− Forecasted total reserves of geothermal energy, including the rock and water in it, are about $315 \cong 10^6$ tones of thermally equivalent oil.

− Reserves in thermal water only are about $20 \cong 10^6$ tones of thermally equivalent oil.

Temperature in the water collector is about 90 – 130^0C, while the output temperatures will be somewhat lower, about 80 – 100^0C.

5. POSSIBILITIES OF USING GEOTHERMAL ENERGY IN SEMBERIJA

Looking on the whole, the hydrogeothermal system allows the use of energy with two aqueous horizons, which are in vertical profile independent of each other, leaving a possibility that somewhere in the hinterland is a unique system of recharge. Temperatures are different, as well as water quantities, i.e. the quantities of energy that can be used. According to the current degree of exploration of the field, taking into consideration the methods of hydrogeothermal modeling that were perfected over the last thirty years, the data were derived about the possibility of exploitation of 500 l/s of thermal waters in the territory of Semberija [22,23].

Using geothermal energy as a replacement energy source in Semberija area is possible for district heating of Bijeljina City, agricultural greenhouse production and for sport and recreational purposes. If in lower aqueous horizons waters with temperature higher than110^0C can be captured, a possibility is opened for its use for generating electrical energy. .

The manner of thermal water exploitation was planned with the use of deep exploitation wells, that will be distributed in a way to capture sufficient quantity of thermal water, without the wells exerting influence on each other during exploitation [22,23]. For longer exploitation time, safe quantities of hot water and energy, keeping the natural balance in geothermal system and in the overall rock mass, in addition to exploitation wells there will be injection wells too. Thermal water which is exploited, after deriving a certain quantity of energy, is returned to geothermal system over the injection well, setting up a state of renewable system and resource as a significant source of energy.

The above-mentioned energy was very little used in the past period, i.e. only for heating of Dvorovi spa. For more than 40 years a possibility of using this energy for district heating of Bijeljina City has been a matter of discussion. Also, the energy may be used with different industrial and other production facilities as a replacement energy source or hot water in technological processes [22].

Based on the analysis of the possibilities of generating energy in one exploitation well during

exploitation of 100l/sec, it is shown that 24,75 MW can be produced, of which one third can be used for heating of the Bijeljina city, because the heat system is set at a temperature difference of 95–75^{0}C [24−26].

Feasibility of use of geothermal energy is manifold, starting with social and economic aspect, as it represents a domestic resource and is independent of export, as well as the environmental aspect as it contributes to preserving the environment. Its use does not produce pollution in the atmosphere or pollution of water, flora and fauna and is not a threat for the health of people. Semberija is an agricultural area, which opens up a possibility of production of healthy, ecologically clean food, where the pollution of air, water and soil are within ecologically permitted limits.

6. FINAL CONSIDERATIONS

The existence of thermal waters in North-East part of the Republic of Srpska, i.e. Bosnia and Herzegovina, connected in the East with West Serbia and in the West with the Posavina basin, has been known for more than a half of century. Despite its being economically better and ecologically cleaner resource, it has not found a wider application as of yet. The presence of fossil fuels as a resource that has a wider application in the energy sector, has slowed down or completely excluded the possibility of use of geothermal energy.

The ever increasing threat to the environment posed by the consequences of use of fossil fuels, demands new solutions in the energy sector, primarily by using renewable sources of clean energy. In that regard, geothermal energy has a special place, with the area of Semberija, which is characterized by thermal waters with the highest temperatures in the Republic of Srpska and close vicinity, being the most promising in that regard. Energy that can be derived from thermal waters may find its application as thermal energy for city heating, in greenhouse production of fruits, as well as for sport and recreational purposes.

Based on detailed explorations of deeper horizons of Triassic limestones, where the waters with temperatures higher than 110^{0}C are expected to be found, opens up a possibility for using this energy for the production of electricity. According to previous explorations with a possibility of exploitation of thermal water of 500 l/sec, a geothermal power plant may be built, with the power of 100 MW, and with an increase in exploitation of thermal water 2 to 3 times, the power of geothermal plan may be increased to 250 − 300 MW.

Geothermal energy, as clean renewable energy, ecologically clean energy regardless of the manner of its use, is the most acceptable from economic point of view. Its use contributes to achieving different effects, which, according to the importance, are the following:

− Ecological – cleaner air, water and soil, which gives a possibility for production of ecologically clean and healthy food, in accordance with valid legislation. Semberija, as an area, may be singled out in the map, as an area with the safe origin of healthy food.

− Economic – because the production of this energy is by far more favorable compared to other energy sources.

− Sociologic – improvement of climate conditions, especially in the city area during the winter period, which has a positive effect on the health of population.

The above-mentioned effects justify the use of geothermal energy as a renewable resource, ecologically clean energy, that can be exploited almost imperceptible for its surrounding.

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ЗНАЧАЈ ГЕОТЕРМАЛНЕ ЕНЕРГИЈЕ НА ПОДРУЧЈУ СЕМБЕРИЈЕ
У РЕПУБЛИЦИ СРПСКОЈ

Сажетак: Све веће потребе за енергијом, али и очувањем животне средине, посљедњих година даје већи значај кориштењу алтернативних обновљивих извора енергије. Један од значајних извора енергије, који налази примјену у свијету више од 100 година је геотермална енергија. Њено присуство у водама и стијенама отвара могућности већег кориштења у различите сврхе. У развијенијим земљама Свијета или у земљама које су више усмјерене на кориштење геотермалне енергије, она заузима значајно мјесто. Ипак, у односу на фосилна горива која су главни извор енергије, геотермална енергија се користи у занемаљивом проценту.

Нагло загађење животне средине, посљедњих година отвара више простора за кориштење геотермалне енергије. Балканске земље заузимају значајно мјесто на геотермалној карти Европе, а Босна и Херцеговина, односно Република Српска се издвајају као значајнији простори на којима је акумилирана геотермална енергија као значајан ресурс.

У Републици Српској се издваја више карактеристичних подручја са присуством термалних вода, али је најзначајније у Семберији, гдје се температура на дубинама од 1200 – 2500 m креће од 75 – 100^{0}C. Могућности кориштења ове енергије су вишеструке, као топлотне за различите сврхе или производње електричне енергије. Њеном употребом на подручју са кога се експлоатише, промијенити ће квалитет животне средине, јер ће у дијелу или цјелости као енергија замијенити фосилна горива.

Кључне ријечи: геотермална енергија, термалне воде, кречњаци, топлотна енергија.